R E P O R T R E S U M E S

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A COMPUTER-BASED LABORATORY FOR AUTOMATION IN SCHOOL SYSTEMS.

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REPORT NUMBER SP-256-000-01 PUB DATE 12 MAR 62
EDRS PRICE MF-$0.25 HC-$0.88 20P.

DESCRIPTORS- *COMPUTER BASED LABORATORIES, *AUTOMATION, SCHOOL SYSTEMS, *SYSTEMS APPROACH, *SIMULATION, ADMINISTRATIVE ORGANIZATION, *COMPUTER ASSISTED INSTRUCTION, CONVENTIONAL INSTRUCTION, EDUCATIONAL RESEARCH, MEDIA RESEARCH, AUTOINSTRUCTIONAL AIDS, SYSTEMS ANALYSIS, GROUP INSTRUCTION, INDIVIDUAL INSTRUCTION,

AS THE EDUCATOR FACES DECISIONS ABOUT NEW TECHNOLOGY, HE NEEDS PRACTICAL RESEARCH ON WHICH TO BASE HIS DECISIONS. A SYSTEMS APPROACH TO RESEARCH, RATHER THAN A PIECEMEAL ONE, IS HIGHLY DESIRABLE. SUCH AN APPROACH COULD EMPLOY SIMULATION TECHNIQUES, WHICH DIFFER FROM CONTEXTUAL ONES PRIMARILY IN SCOPE AND CONTROL, AND WHICH CAN DEAL WITH A WIDE RANGE OF ALTERNATIVES, DECISIONS, AND INTERPRETATIONS. ACCORDINGLY, THE SYSTEM DEVELOPMENT COPRORATION HAS CONSTRUCTED CLASS, A COMPUTER-BASED LABORATORY FOR THE STUDY OF AUTOMATED SCHOOL SYSTEMS. IT CAN PROVIDE AUTOMATED INSTRUCTION FOR INDIVIDUALS AND GROUPS, CONVENTIONAL INSTRUCTION FOR GROUPS, CUMULATIVE AND IMMEDIATE ANALYSIS OF STUDENT PERFORMANCE WITH RESULTS DISPLAYED FOR THE TEACHER IN REAL TIME, AND CENTRALIZED DATA PROCESSING FOR ADMINISTRATIVE GUIDANCE AND PLANNING. (BB)

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(SP Series)

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PREFACE*

There are few persons who, upon a moment's reflection, do not recognize the uniquely important role education inevitably must play in the lives of all men in the future--a role more important than any other human activity or endeavor, because all other efforts, e. g., the obviously important expansion of scientific understanding and applications, of social and economic developments, of improved communications among peoples, or of international diplomacy--all interact intimately with education. All are dependent upon education for their development and dissemination.

To better achieve this role, I suggest, and urge, the establishment of a Center for Advance Systems Planning and Developmental Research for Education. This would be a Center at which would be undertaken intensive interdisciplinary systems study and advance planning and research for educational programs (both "instructional systems" and "administrative and support systems") at all levels of education, from elementary school through university. It would provide not only for "out-in-front" thinking, but also for systematic and successive tryout of educational ideas and processes and materials, in both simulated and field situations, followed by revision, as required, to adapt educational practice to the projected economic, scientific, and social needs of the future. I believe it is imperative that the results of educational planning should be carefully researched and adequately tried out before the new developments and advance ideas are implemented in any ongoing educational program. This means both exploratory determinations of significant variables and systematic and critical research of the ideas growing out of educational planning, seeking, first of all, to identify the important subsystems that are important in practical school situations, and then to conduct carefully designed research through field try out and laboratory simulation. As an example or approximation of the kind of flexible simulation laboratory needed for a center of advanced study in education, I would describe the Computer-Based Laboratory for Automated School Systems (designated CLASS) now in use at the System Development Corporation. This laboratory enables our staff in the Automated Education Project at SDC to apply empirical procedures in the study of the dynamic functions of a simulated educational system. With a large digital computer at the base of the system, considerable flexibility and control over the "school" environment can be achieved.

Before implementing educational ideas and new developments in a wide variety of situations on a large scale, the exploratory study, laboratory simulation, and field testing should be extended and evaluated in full-scale operations involving broad educational programs. The techniques and procedures should be tried out with adequate replication to determine those that hold up, in

*These remarks include excerpts from the Presidential address to the American Educational Research Association at its annual convention, February 1962, by Dr. D. G. Ryans.

that they are widely generalizable. Such study should be conducted under closely observed conditions--not necessarily experimental conditions, in the narrow sense of that term, but under conditions which permit appropriate evaluation of practices prior to their wider application.

After ideas have been conceived, and developed, and properly researched and tried out, if they are found to be worthy and practicable, it is imperative that they be communicated--that they be made readily available and that their implementation be encouraged and urged. It is important that adequate storage and information retrieval methods be developed which will make the usable information about advance educational practice and new developments immediately and rapidly available.

If, following the foregoing sequence of advance planning and study, certain resulting educational developments survive and prove sound, it is equally imperative that they be energetically and impressively "sold" to educational practice. New ideas, techniques, and materials should not be presented "cold" to the educational practitioner; rather, adequate methods for orienting the administrator and teacher to their use, perhaps detailed teaching and demonstration methods (e. g., regional pilot demonstrations for teacher-administrator training) should be provided to encourage maximum utilization of the ideas, techniques, and materials.

This forward-looking planning, and associated developmental research, I consider the most important of all possible things we should be thinking about in education today.

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A Computer-Based Laboratory for Automation in School Systems

Don D. Bushnell and John F. Cogswell

The weight of time and numbers on our educational institutions has already been well documented. Straining to teach more students with proportionately fewer teachers and required to re-educate an increasing portion of the working population, schools and higher institutions have been under pressure to develop a modern educational technology.

Finn (8) has indicated two major trends in this development: (1) a mass instructional technology such as educational television, and (2) a technology for individual self-instruction primed by the development of automated teaching devices. He predicts that these developments are going to "hit education with a million pound thrust."

The problem has been to refrain from a piecemeal approach to a technology of education with the emphasis on some educational objectives to the exclusion of others. Melton (9) said that in the development of a modern technology, a taxonomy of education should guide the evolution of new techniques so that proper objectives of education are served. Certainly the manufacturers of technological equipment are not in the position to consider objectively the merits of their technology for achieving these goals. Nor is the science of learning prepared at this time to lead an orderly procession of innovations into the classroom.

It is the educator who is faced with a problem of making decisions about new technologies. These decisions are best based on developmental research conducted at the point of application. It is a problem of research because the evaluation of any new educational media should be in terms of measurable achievements. And it should be conducted at the point of application, as Hilgard (12) states it, "because educational research requires a strategy of participation and decision-making so that proven results will become a part of practice."

But how does the educator avoid the piecemeal approach to the development of a new educational technology? How does he achieve the right perspective for the integration of the newer educational media with the marketing world, the huge resource foundations, and the science of learning making claims for this or that innovation?

It was largely the consensus of last year's symposium at Stanford University (12) on the state of research in instructional television and tutorial machines that a systems approach to education was needed to avoid the pitfalls of overemphasis on any one media. A systems approach to education as Carpenter put it:

> " . . . would provide: A conceptual framework for planning, orderly consideration of functions and resources . . . and the kinds and amount of resources needed, and a phased and ordered sequence of events leading to the accomplishment of specified and operationally defined achievements." (p. 75)

A SYSTEMS APPROACH TO EDUCATION

Any arrangement of men and machines bound together to produce a specifiable output can be referred to as a "system." The output of an educational system is, of course, educated people. Thus Pythagoras and his stick with which he taught theorems to students by drawing in the sand is an early man-machine system; just as a university with its physical plant, its teachers, blackboards, books, card punch machines, etc., is also a man-machine system.

Generally speaking, the output of a modern educational system is a result of a complex of interrelated factors. The systems approach to this complexity is to functionally describe the men and equipment in the system; analyze both the informal and formal communication channels and the informational needs of those involved in the system (in this case educators, students, and parents); determine costs of the present system requirements; and relate costs to the output of the system.

Two methods of systems analysis have been in general use. Neither of them is entirely new to education. One involves mathematical modeling and the other simulation techniques.

Mathematical modeling

Kershaw and McKean (7) of the RAND Corporation did an exploratory study for the Ford Foundation to assess the possibilities of making quantitative comparisons of elementary and secondary school systems. They conclude that data collected from a large sample of schools can result in a meaningful comparison of the effect of different input variables on educational achievement. Innovations, such as educational television; changes in a school system, for example increasing teacher salaries; and differences between schools, i.e., pupil-teacher ratios--all of these can be costed and related to output measures like standard test scores. Kershaw and McKean propose that this kind of statistical analysis will be of the sort "that can help administrators and others choose improved educational systems."

The University of Pittsburgh with the American Institute for Research (11) has undertaken a study which, among other things, will relate various school characteristics to the performance of pupils on specially designed achievement tests. Similar to the study proposed by Kershaw and McKean, this analysis will be based on certain mathematical models to help determine which school characteristics produce significant differences in pupil performance. About 500,000 pupils in approximately 1,400 secondary schools will be included in the sampling.

Development of simulation techniques for systems analysis

Although comparative statistical analysis of different schools should yield important information, it is clear that this approach does not provide a solution to the developmental problems associated with the application of new technology.

Military operations were among the first to recognize the advantages of system analysis and research for the development of vast automated weapons systems such as the Strategic Air Command and the Air Defense System. But because of the complexities of their systems, it was found that the use of mathematical models for the description of the variables in the system often defied their system analysts. It was found that simulation of the system, sometimes with the aid of a digital computer, offered a valuable alternative to abstract analysis.

The Systems Research Laboratory (4) at The RAND Corporation, was used to simulate a model of an Aircraft Control and Warning Squadron. The simulated environment of radar targets, weather reports, air base and weapons status reports, and messages from adjacent control centers was genuine enough for crews to respond to in a realistic manner. The interactions of the men and their uses of communication channels under simulated war conditions was studied. The experiments that ensued not only demonstrated the value of simulation for systems research, but also indicated that crews actually learned and improved their operational capability in the simulated environment.

Thus simulation provided a means for both systems research and training. In fact, the Air Defense Command considered the training value of the technique so great that they contracted with the System Development Division of RAND (later to become the System Development Corporation) to train all of their air defense crews throughout the country with the methodology developed in the laboratory.

Today most prime military systems have associated with them a secondary system (a simulated system) established for the express purpose of studying and improving the prime system.

Of more immediate interest to educators are the simulation studies carried out under the sponsorship of the University Council for Educational Administration (13). Several universities have used films, film strips, tapes, and printed materials developed by the Educational Testing Service for simulating situational tests for researching certain patterns of successful school administrative behavior. An in-basket technique was used to present secondary school principals with routine and problem situations. Tapes and films presented circumstances demanding immediate action.

Although the UCEA program was developed primarily for research, it was reported that those who experienced the simulated situations felt the simulated materials held promise for instructing school administrators and for providing a better basis for selecting principals.

Simulation and contextual research

The study and comparison of different means of accomplishing educational objectives through simulation techniques is not unlike contextual research, i.e., research done in real education settings. The differences are primarily in the scope of study and in control. Contextual research has generally not dealt with the wide range of alternatives, decisions, and interrelations that must be considered if the output of our educational systems is to be improved. Nor has it generally dealt with sufficiently purified variables to be "scientific."

On the other hand, systems research utilizing simulation techniques has the advantage of a realistically simulated environment and a good measure of control. System simulation and research methods could lead to the optimization of new technologies in the realistic setting of the classroom for the following reasons:

1. It yields information about unpredictable effects that might be costly if they occurred for the first time in a real school (remembering educational TV and Compton College.)

2. It permits the training of educational personnel and the development of organizational procedures appropriate to the new media.

3. It prevents a piecemeal approach to the development of an instructional media since new technologies are tested in a total plan of instruction.

4. It involves the educator in the research as a member of the research team and would demonstrate the desirability of new technologies to those who make decisions about their acceptance in education.

5. It allows the projection to future configurations presently not existing by simulating and testing the functions of proposed models.

The need for simulation laboratories

A system simulation research approach requires a facility in which simulated schools, materials, and situations can be used and experimentally studied. This facility can be as simple as a single office where in-basket techniques are used, or it can be as complex as the Systems Research Laboratory developed for the RAND study.

What is needed, said Carpenter at the Stanford symposium, are research centers in which a wide range of research with educational media could be accomplished. These centers would be well housed and well equipped for advanced research on educational innovations and learning processes and would provide sustained support for systematic and programmatic research. Because simulation research provides realistic tests under realistic conditions, the centers could "communicate" applicable information about new media, new practices, and research results to the educational community.

Carpenter seems to be seconding an earlier statement by Melton (9) at a Northwestern University symposium (on the topic: "Can the laws of learning be applied in the classroom?"). Melton said there is a critical need for laboratories where the science of learning and the technology of education is developed side by side, and where the sampling of subjects (both curricular and human) is representative of those whose learning is to be managed in schools.

An adequate facility for developmental research on educational media should accord the experimenter multivariable controls. The flexibility for both mass and individualized media should be realized in different teaching situations for different subject materials. Implications of new techniques and new data for the total educational system should be capable of investigation. Finally, it needs to be emphasized that the ultimate test of educational models, even though developed and evaluated under realistic conditions in a systems simulation laboratory, is the trial in actual school systems.

A COMPUTER-BASED LABORATORY

A computer-based laboratory for the study of automation in school systems, (designated CLASS) is now in construction at the System Development Corporation. This laboratory, like those contemplated by Melton and Carpenter, should help educators move in the direction of greater communality between "the science of learning and the technology of education."

The CLASS facility in the large man-machine Systems Simulation Research Laboratory at SDC will be devoted to educational research and development of educational technology in a systems context. The laboratory permits the integration of (1) individual student automated instruction, (2) group instruction (both automated and conventional), and (3) centralized data processing for administration, guidance, and planning functions. This educational system is now in construction and should be completed by the ·umer of 1962.

Flexibility has been the primary aim in the design of CLASS. The central control of the laboratory is exercised by a large digital computer, the Philco 2000. In addition to providing multivariable control, permitting individualized auto-instruction, and providing detailed recording and computation, the computer facilitates flexibility of experimental design. Various innovations in instructional mode, administrative data processing, and counseling procedure can be provided by computer-program modification. The facility itself will consist of an administrative area, a counseling and observation area, and a large automated classroom area. In Figure 1, the classroom area has been divided into two rooms by a sound-attenuating folding wall. This wall makes it feasible for two teachers to be simultaneously teaching in two different subject matter areas and in two modes of automated instruction. When the wall is recessed, a large group area is accomplished.

The observation area incorporates a small counseling room. The desk in the counseling room will have an alphanumeric typewriter, connected to the computer, for recording and reporting diagnostic data and for calling up information needed by the counselor during an interview. All of this data will be stored on magnetic tape along with the student's educational record (continually updated by his daily performance), previous school record, aptitude measures, and other relevant information.

In the observation area, observers will be able to monitor the behavior of students and teachers in the classroom through a one-way vision glass. In the event that the wall is used as it is in Figure 1 to divide the large area into two classrooms, a closed-circuit TV camera and monitoring unit permits observation of the remote classroom. Microphones placed in the classroom(s) will also permit observers to monitor the auditory behavior of subjects.

The administrative area will be the focus for the planning, administrative, and logistical functions normally associated with a school system. Initially, the off-line printer associated with the computer will serve as a general purpose print-out facility for the administrative area. Thus the computer will provide the means of recording and calling up various kinds of information such as daily attendance, student progress, etc. In addition, the computer can be programmed to perform the tasks of registration, class scheduling, bus scheduling, financial accounting, enrollment forecasting, etc.

At a somewhat later date, it is anticipated that additional equipment such as a card punch, a Flexowriter, and electrical typewriters tied to the computer will be installed; as greater flexibility in information processing is required, other components will augment the system.

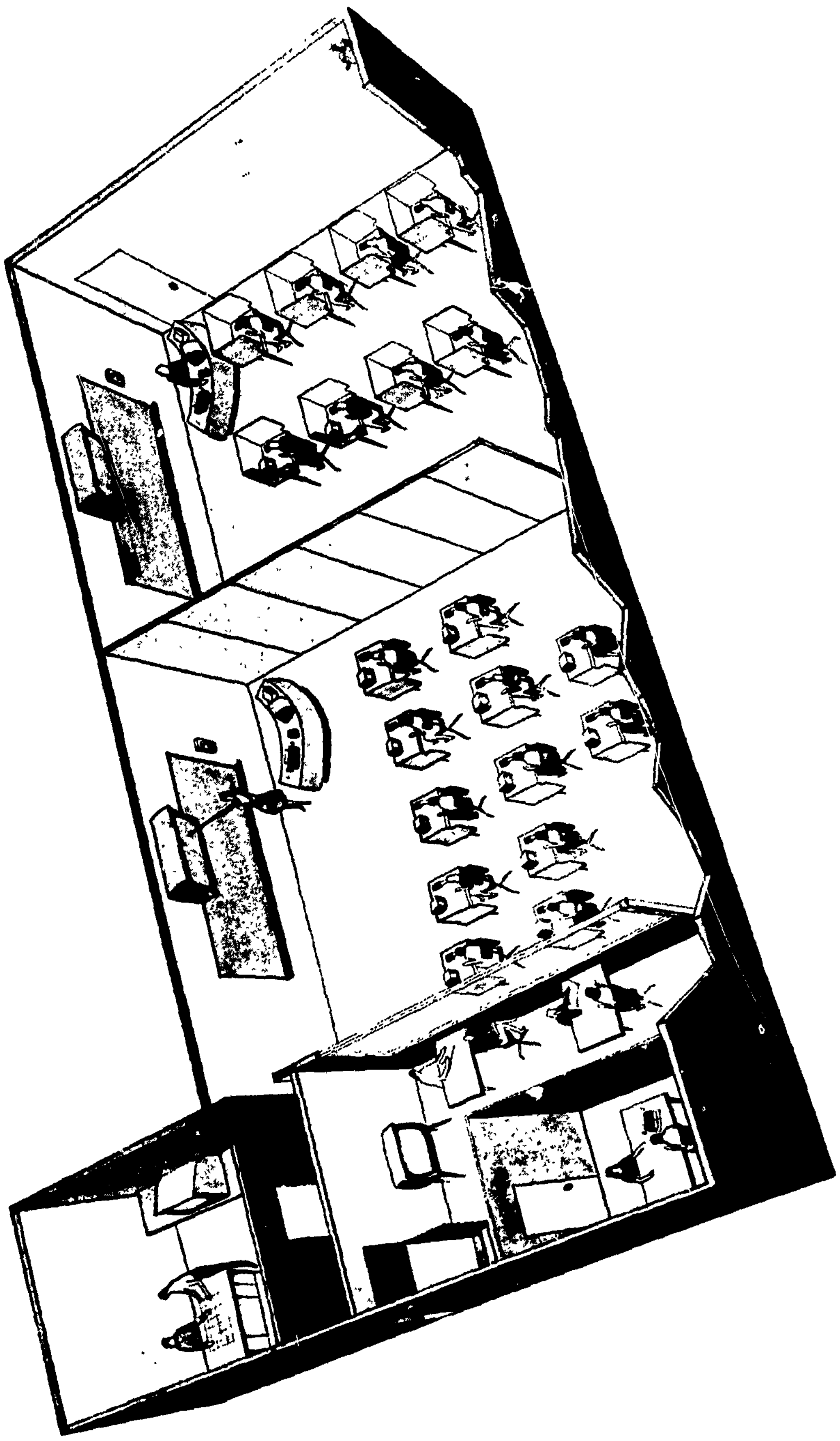

Figure 1. The CLASS Facility

The illustration shows, moving from left to right, the administrative area; combined observation and counseling area; and the large classroom area divided into two classrooms by a sound attenuating folding wall.

The classroom area has been designed with thirty square feet of space allowed for each of the twenty students. This of course includes walking space, coat racks, and cupboard area in addition to the student's desk and chair. Cabling attachments for the electronic components in the classrooms are unexposed because of a false-floor construction.

The individual mode of auto-instruction

Individualized automated instruction, as described by Coulson and Silberman (5), is made possible through the electronic components on each of the student's desk. Each student has the two components shown in Figure 2--a film viewer and a response device connected through a buffer system to the computer.

The student begins with a sequence of educational items or frames, as displayed on his film viewer. All of these items have been carefully written, sequenced, and tested in the same manner as most auto-instructional programs. Some of the items will be multiple-choice questions testing the student's knowledge of the subject material. The student responds to the question by pressing one of five keys on his response device. When a key is pressed, a light inside that key is turned on. After the student is certain of his selection, he presses the "Enter" bar, transmitting the final response to the computer memory. The computer analyzes the response and gives appropriate knowledge of results by lighting a second light above the response key corresponding to the correct multiple-choice selection. A red or a green light at the top of the response device can be turned on by the computer also indicating correctness of choice.

Every item number presented to the student via the film viewer is registered within the computer control unit. Each student response is checked for correctness and the appropriate feedback message is transmitted. A cumulative record of the student's performance on each of the topics is kept. These performance measures include the student's response time, error count, and pattern of errors. If a student's performance falls below a certain level for a particular topic, the student is "branched" or detoured to a special set of remedial items on that topic. The student may be taken through the entire remedial routine, or may be brought more quickly back to the basic series if he performs well on the remedial set. If he makes a good record on any given topic, demonstrating by his overt behavior that he understands that topic, he may not be branched at all but may proceed rapidly, skipping some material as he proceeds.

When the student has read a frame of material, responded to the diagnostic question, and recieved knowledge of whether his response was right or wrong, he is ready to continue. He presses the "Enter" bar again, turning off the lights on the response device; the number of the next educational frame appears in the read-out panel of the response device. He then manually winds to the frame number indicated by the computer.

Figure 2. The Student Teaching Components

This student is carrying out self-instruction with a manually operated film viewer on the left and a response unit on the right.

At various stages during the training period, the student may be required to evaluate his own progress. If he expresses a feeling of confusion, he may be taken to a remedial branch even though his actual performance is above the criterion level for such a branch.

If a student does not perform well in his subject area and needs excessive remedial work, an auxiliary program can be read in from magnetic tape. The student can now proceed on a new series of educational items which could range from a different training approach to a change in media.

Three control buttons, which will not be activated in the initial experimental period, have been added to the response device for actions to be taken by the student. For example, he may want to call the teacher, back up to a previous item, or move forward to a new kind of topic.

The manually operated viewing device, which presents the instructional items, will hold microfilm strip with a capacity for ten thousand frames. The illumination of the screen will be sufficient for reading under daytime ambient-light conditions. Each student's desk is equipped with movable independent-study panels that can be easily brought into place, and when not in use become a part of the desk.

The teachers' components

The teacher in CLASS will have four sources of information available with which to monitor student learning behavior: (1) a teacher's display console, (2) an educational data display, (3) a response device similar to the student's unit, and (4) a film viewer for monitoring the educational program. As seen in Figure 3, the teacher's display console has ten switchlight buttons, each button corresponding to a single student. Five "Action" buttons are located in the middle of the console; each of these corresponds to a different kind of action to be taken by the teacher. An "Enter" bar allows a change in the selected action before the final response is entered into the computer.

When an instructor initiates a period of automated individual instruction (as shown in the classroom on the right in Figure 1), he inputs the student assignments from punched cards, presses each student's button on his console, activates the first "Action" button, and enters this action into the computer. This causes the Student History Tape to be brought into the computer memory indicating where the student is in his lessons, his IQ, and previous grade record. Another magnetic tape (the Subject Matter Tape) will be read into the computer, assigning the day's lessons to each student.

As the students input their responses to the educational items, the computer monitors individual student response behavior and lights the button on the teacher's console of any student who is experiencing difficulty; that is, any student who makes a certain number or pattern of errors or has an excessive

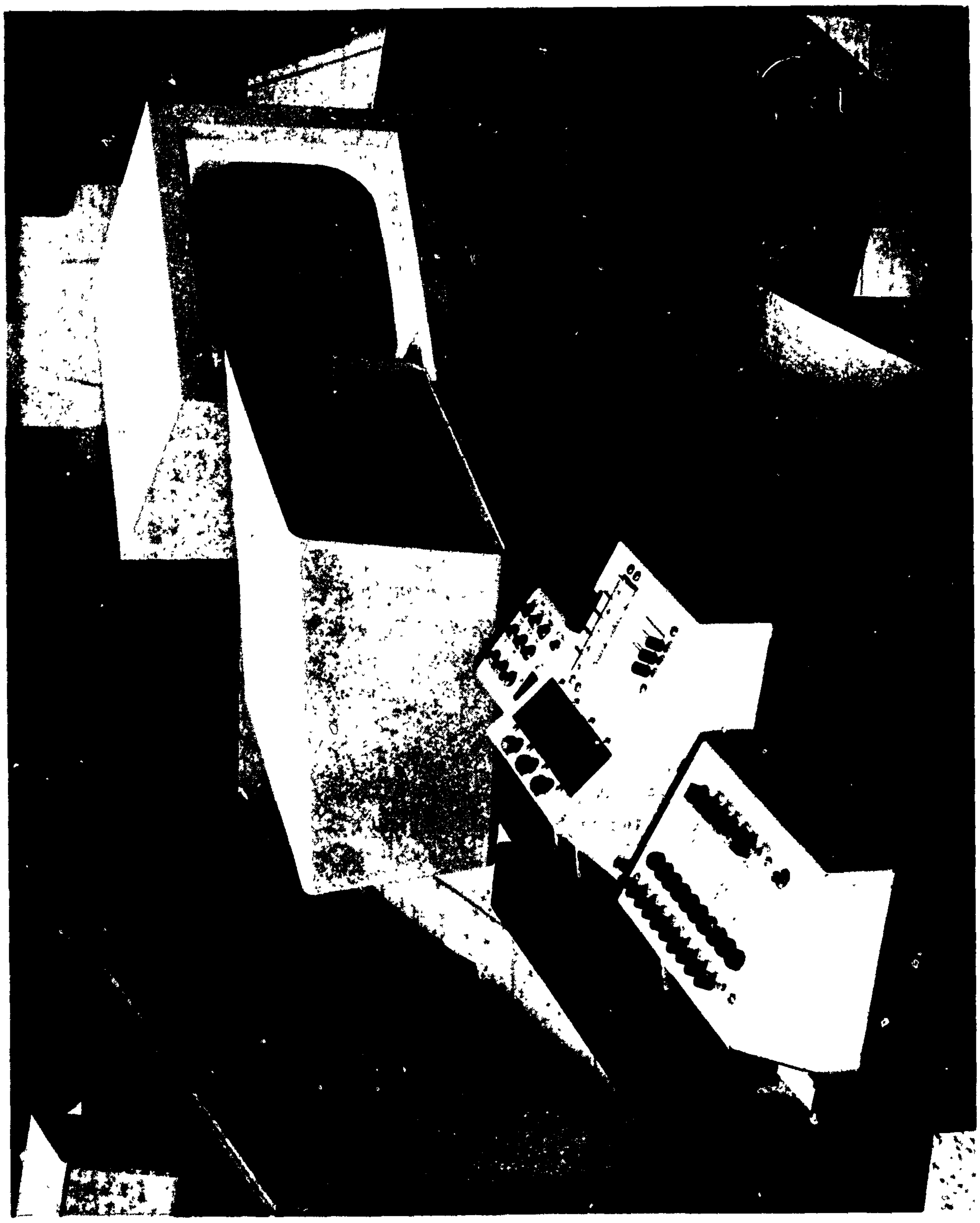

Figure 3. The Teachers' Components

The illustration shows, from left to right, the teacher's console, response device, audio-visual control panel, film viewer, and educational data display.

response latency. The teacher responds to this forced display by pressing the button which has been lighted (which turns out the light), and pressing the second "Action" switch on her console, and entering this action into the computer. In response to this action, the computer causes the educational data display to read out information on the individual student's performance and sets the teacher's response device in parallel with that student. The teacher can continue to monitor the student by observing his responses on the response device which has the same keys being lighted and receiving the same feedback messages as the student's. The film viewer of the teacher enables him to read those same items with which the student is apparently encountering some difficulty. During the training period, following the automatic tutoring session, the teacher can talk with each of the students he has monitored or amplify the topic areas in class discussion where some of the students appeared to be having difficulty.

The other "Action" switches on the teacher's console will eventually be programmed for several different kinds of actions to be executed by the instructor. He may want to call up different kinds of data on individual students or receive automatic print-outs on students fitting certain categories such as most advanced or least advanced with regard to the subject matter under study. The console also enables the teacher to activate only certain student components when it is desirous to mix the instructional modes. Some students who have been absent because of illness may need more individualized machine tutoring to bring them up to date; in other cases, individual student aptitudes may cause some to take more remedial training while the remainder of the class carries on group discussion.

A group mode of instruction

It has already been stated that CLASS flexibility provides teachers with the possibility of students working individually at self-paced speeds and on different material, in large groups, or in mixed groups where some are individually tutored and others receive group instruction. In all cases, however, immediate analysis of student performance provides the teacher with prompt diagnosis of student weaknesses since the computer maintains continuous records of performance data. The teacher is thus liberated from most record-keeping, paper-grading tasks no matter what the mode of instruction.

In the group mode of instruction (as it is being conducted in the classroom area in Figure 4), the TV screen and speaker serve as a common group output for different kinds of audio-visual presentations. An audio-visual system of remotely controlled slide and film projectors modeled after a system proposed for the University of California at Los Angeles (1) is incorporated in CLASS. This system enables the teacher to (1) call up films or other displays from the front of the classroom, (2) stop frame the display whenever appropriate for group discussion, (3) repeat short film strips or sequences of film when needed for repetitive learning, and (4) select a particular slide at the

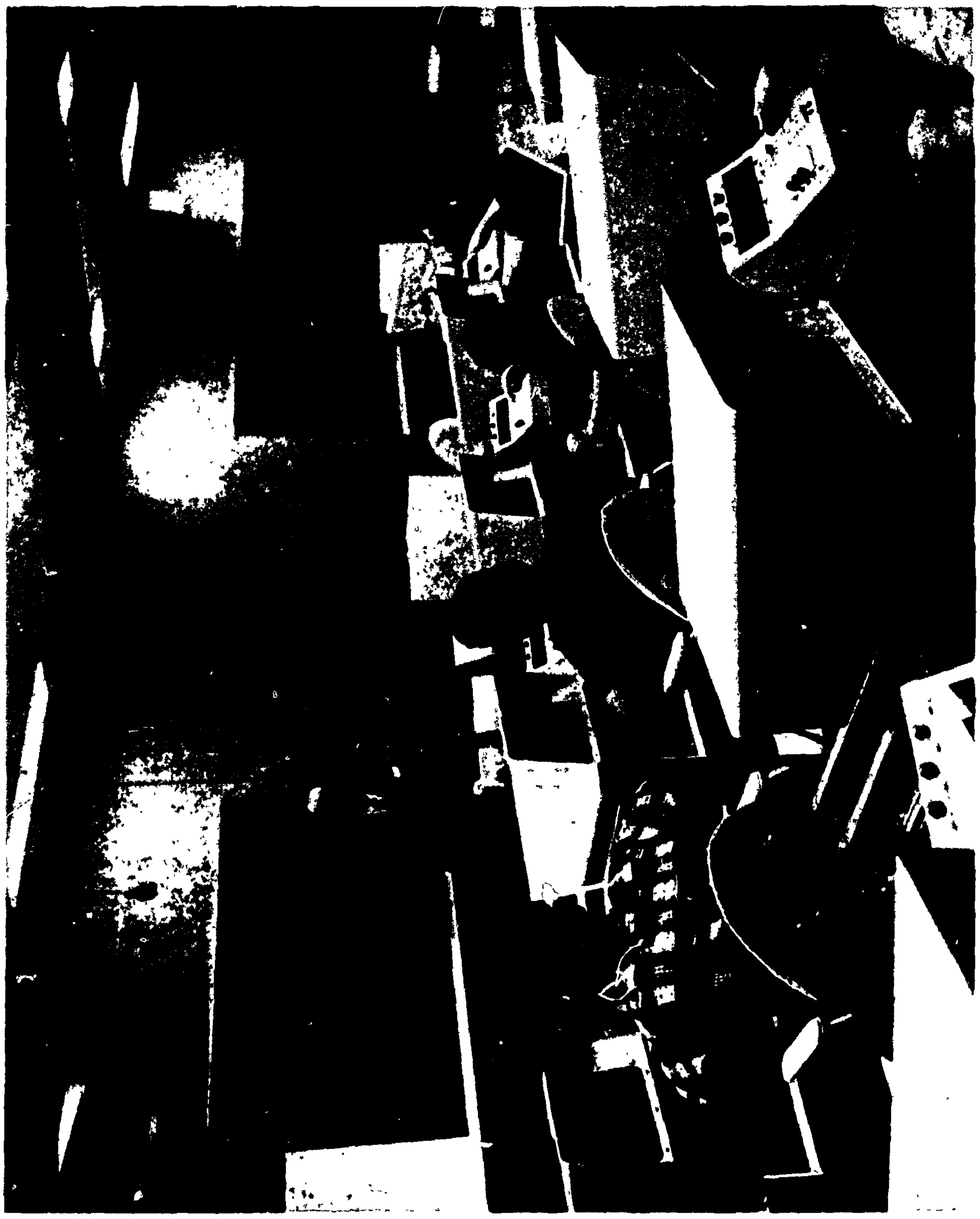

Figure 4.

Students in CLASS are learning French in a group mode of automated instruction. The teacher sequences the educational items presented to the students via the closed-circuit TV system and the students respond to questions in French about the pictures shown. The computer records and analyzes student responses and presents displays to the teacher in real time.

teacher's command. It also accords an important ease of scheduling and calling up displays at the moment they're appropriate to the topic being taught.

During the actual class period, the instructor can book a film or series of slides for a specific time. When it is appropriate, he switches on the TV screen, turns to the channel where he sees the first frame of the film or slide he is going to use. It will not be necessary to darken the room. Whenever, during his lecture, the instructor wishes to run his film or slide or stop on a frame, he presses a remote-control button appropriate to the action. A call to the projectionist in the audio-visual center can arrange for additional films or magazines of slides.

If the teacher intersperses his lecture with diagnostic questions which both demand the student's attention and test his understanding, he will receive immediate read-out on his educational data display of certain group, subgroup, or individual student measures indicating the degree of understanding and helping him to redirect his instruction. He can also signal the correct response on the student's response devices by activating the device at his desk.

An automated group-education session, without teacher intervention, can be effected by computer control of the random-access projector now being used by the Automated Education Project at SDC. This projector holds up to six hundred 35-mm slides. Under control of the computer, any one slide can be selected in a maximum of twelve seconds. Group knowledge of results can be achieved simply by giving the correct answer on a slide following each educational item which has a diagnostic question associated. Individual feedback is of course supplied on the student response device. Thus many of the properties usually identified with individual teaching machines (2) such as correction feedback, controlled sequencing, and prior programming can be gained in the group-instructional situation by the use of the computer analysis and control programs.

When a mixed mode of instruction is to be carried out in one classroom--that is, when some students are taught in a group mode and others are working individually--an audio output over individual headsets will be made possible by connectors at each student's desk. One desk will be equipped with a prototype unit which will simultaneously present film strips and sound associated with each frame. The sound record is photographically printed on the same film which carries the picture. Eighteen seconds of sound recording can be stored on each frame. With this unit, a single student can be machine-tutored by a teaching machine which has both random-access slide and audio display. This could be an important capability when researching the respective merit of different sense modalities for individual student aptitudes and for different content areas.

Immediate plans for CLASS

Concurrent with the construction of the CLASS facility in the Systems Simulation Research Laboratory, the authors conducted a system analysis of a school system.

The analysis yielded a functional description of the subsystems and the interactions between subsystems. Particular emphasis was placed upon description of different media that are utilized in teaching and the flow of communication between students and teacher. Answers to questions such as the following were sought: Who provides what information to whom? What are the system requirements, i. e., reporting practices, tracking and advancement requirements, equipment utilization, etc? What parts of the total educational system are affected by different actions taken by other parts?

The instruction in a particular educational subject matter, such as English, will be selected for intensive investigation. Special attention will be paid to those aspects of the system where information processing, decision-making, teaching, counseling, and general system performance might be improved by new technological innovations. Some consideration will be given of what could be automated and what should be left as currently performed.

Following the system analysis and the completion of CLASS, simulation studies will be conducted to determine the effects of improvements in system operations. For example, if immediate and accurate information is provided by the computer on the state of academic knowledge of each student, what effect does this have on teaching, administration, and counseling? What would be the implications of individualized automated teaching for curriculum planning, for building construction, and teacher preparation?

Other studies might be based on extrapolations from the data of basic research. The computer could be programmed to simulate the responses of students in accordance with a model based on research findings. The responses of teachers, administrators, and counselors to the simulated data could be studied. In addition, simulation of various student outputs could be used to determine the training value.

Finally, the results of basic and systems research and a system analysis will lead to modifications and improvements in the design of the laboratory itself. The systems analysis and simulation studies will yield recommendations for the redesign of present school systems and for a prototype of tomorrow's school system.

Blue sky

Considering the cost of computers, how feasible is a computer-based educational system? The answer would have to be "not very" if a large central computer were required for every school. But computers are being installed and used in several school systems. For example, the California Department of Education, under the auspices of the NDEA, is currently conducting practical studies in the application of electronic data processing for pupil personnel services at the secondary level. Five schools in the Richmond (California) School District are successfully being serviced by a central computer facility. Similarly, we may contemplate a powerful miniaturized computer of the future processing data obtained from large numbers of students in several schools. It is conceivable that with a moderately large computer, several hundred students could be simultaneously and individually tutored. In the group mode of instruction, when the entire class is receiving the same instructional material, the only limitation on the number of students that can be tutored depends on the nature of the analysis of student performance that has been requested. A concomitant increase in productivity per man-hour of teaching effort would help to offset the cost of the computer. Increased efficiency in the data processing tasks of administrators and counselors would also be a factor to consider. But perhaps the most important consideration is the education in depth that Skinner (8) proposed in his now historical article, "The Science of Learning and the Art of Teaching."

It is easy to speculate on the future automated university or secondary school system. Visualize a computer based library connected to a national library system where students seated in front of consoles can call up information on the current state of knowledge in any area of the sciences or arts. Consider a student study area where students in their individual study cubicles are instructing themselves with the aid of a machine tutor which is linked via the school-system computer to a national information-retrieval system that is processing written data into courses of study, developing diagnostic questions, and searching for answers to questions students ask. The same computer that serves the students can be accumulating data and performing analysis for the educator.

Present developments and apparent trends in technology allow us to make some fascinating predictions regarding the future. In the final analysis, however, the future depends upon a long series of studies in basic research, systems research, and experience in actual school situations.

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